U.S. Department
of Transportation

**Federal Aviation
Administration**

Memorandum

Subject: **ACTION**: Review and Concurrence, Equivalent Level of Safety Finding for Cessna New Model 680, APU Indications
FAA Project #TC2548WI-T

Date: April 28, 2004

Reg Ref: §§ 25.1305, 25.1549

From: Manager, Propulsion/Mechanical Systems Branch, ANM-112

Reply to Attn. of: Bob Adamson, ACE-118W

To: Manager, Wichita Aircraft Certification Office, ACE-115W

ELOS Memo #: TC2548WI-T-P-1

Background
The Cessna Model 680 will have as standard equipment a non-essential, flight operational APU, which incorporates an electronic control unit that provides complete monitoring and control of the APU with digital-only displays of rotor speed and exhaust gas temperature. The installation will not have cockpit displays of oil pressure or oil temperature.

It is generally accepted that digital-only displays are often less effective than conventional analog displays at providing the crew with: discernible indication of the parameter during a rapid transient, quick intuitive indication of the parameters approximate level, direction and rate of change, proximity to limits, and relationship to other parameters on an existing engine.

Modern APU installations typically use digital displays in conjunction with an electronic control unit designed to maintain all APU operating parameters within safe limits. Should a monitored parameter reach its operating limit, or a fault develop, an automatic APU shutdown is initiated by the electronic control unit. Therefore, it is appropriate that the need for some of the instrumentation required by FAR 25 may be obviated if the automatic features of the APU and its installation duplicate the actions that would be taken by the flight crew in the event of an APU fault or limit exceedance.

It is the intent of §§ 25.1305 and 25.1549 to permit crew monitoring and corrective action for engine exceedances that could jeopardize continued safe flight. Containment capability and other safety considerations are predicated on operational limits being observed and adhered to and any engine redline exceedance must be considered hazardous. Therefore, it is imperative that any automatic engine control design have sufficient reliability to act in place of the crew to prevent any limit exceedance under any foreseeable condition. Automatic features provided within the APU design are intended to minimize the need for crew monitoring and intervention.

Applicable regulation(s)
Sections 25.1305(a)(4), (a)(5), (a)(6), (c)(1) and (c)(3) – Powerplant Instruments and §§ 25.1549(a) through (c) – Powerplant and auxiliary power unit instruments

Regulation requiring an ELOS
Sections 25.1305(a)(4), (a)(5), (a)(6), (c)(1) and (c)(3) – Powerplant Instruments and §§ 25.1549(a) through (c) – Powerplant and auxiliary power unit instruments

Description of compensating design features or alternative standards which allow the granting for the ELOS (including design changes, limitations or equipment need for equivalency)
The following applies to the Cessna Model 680 standard equipment APU installation:

Indications of exhaust gas temperature (EGT) and rotor speed (RPM) are provided by digital-only displays. "MAX RPM" and "MAX EGT" are placarded. Oil pressure and oil temperature are not displayed in the cockpit. The intent of §§ 25.1305 and 25.1549 are to provide an indication to the flight crew when the subject operational limits are being exceeded, thus alerting the flight crew to take appropriate corrective action. This intent is addressed by the APU's electronic control unit (ECU), which provides complete monitoring and control of the APU, including oil pressure, oil temperature, EGT, and rotor speed. If any of these parameters exceeds operational limits in flight or on the ground, or the ECU detects an internal fault, the ECU initiates a protective shutdown of the non-essential APU, and alerts the crew by illuminating the "APU FAIL" light on the RH main instrument panel. If any sensors or associated sensor wiring other than low oil pressure (LOP) fails during APU operation, the resulting open circuit or lack of RPM signal will be immediately sensed by the ECU, resulting in a protective shutdown with the crew alerted by an illuminated "APU FAIL" light.

The LOP sensor and associated wiring is tested at APU start up. Low oil pressure warning, as required by § 25.1305(a)(5) will not be directly provided, but the APU will be automatically shut down by the ECU should this exceedance occur, and the crew will be alerted to the shutdown by the "APU FAIL" light.

The following regards the Cessna Model 680 Sovereign's optional Honeywell RE100[CS] APU installation:

Oil Pressure, § 25.1305(a)(4) "indication" and § 25.1305(a)(5) "warning": The normally closed LOP switch uses a single set point to sense low oil pressure. If oil system pressure is above the preset spring force maximum, the switch remains actuated (open). If pressure falls below the preset spring force minimum, the spring snaps back and the switch deactuates (closed), a condition sensed by the ECU as an indication of low oil pressure, and a protective shutdown is initiated. During automatic pre-start Built-In-Test (BIT), the ECU verifies the LOP switch and wires form a closed circuit. If the circuit is open, the ECU illuminates the "APU FAIL" light, and inhibits the start. During an APU start, if oil pressure is not adequate to actuate the LOP switch 10 seconds after APU speed reaches 95 percent, the ECU initiates a protective shutdown.

Oil Temperature, § 25.1305(a)(6): The high oil temperature (HOT) sensor is a two-wire nickel-type resistance temperature device (RTD) used to measure APU oil temperature. The resistance-temperature characteristic conforms to MIL-T-7990, Table 1. The HOT RTD is continuously monitored during APU operations.

If the resistance level of the HOT sensor exceeds an associated temperature value, the ECU initiates a protective APU shutdown. If the sensor or its wiring fails, creating an open circuit, the resistance increases above the preset level and the ECU shuts down the APU.

EGT, FAR 25.1305(c)(1): The APU cockpit control panel in the Model 680 Sovereign includes a reference digital display of EGT. For redundancy purposes, the EGT measuring system used on the RE100[CS] APU consists of two Type K (Chromel/Alumel) thermocouples mechanically and electrically paired in one sensor that averages their signals. This sensor is connected to the ECU, which initiates a protective shutdown if EGT exceeds a preset value during steady state operation, or a transient higher value during starting. The ECU will also partially close the bleed air valve (BAV) if EGT rises above the preset bleed shed point during bleed air operation, thereby lowering EGT temperature. If the thermocouple fails, a protective shutdown is initiated.

Tachometer, § 25.1305(c)(3): The APU cockpit control panel includes a reference digital display of APU speed in percent RPM. The rotor speed sensor consists of a single monopole with one coil. The frequency and amplitude of the signal generated by the monopole is proportional to the APU speed. The monopole-signal pair (a signal and return) are input to a dual-threshold signal-conditioning circuit in the ECU. The ECU checks the frequency of the speed sensor output voltage changes to sequence events during APU operation and prevent overspeed. In the event an overspeed is detected, a protective shutdown is initiated. Any monopole failure detected by the ECU during APU operation or start up will cause the ECU to initiate a protective shutdown or terminate starting, and set a start inhibit, which will prevent the APU from starting. The ECU will also illuminate the "APU FAIL" light, alerting the crew of a problem. The RE100(CS) APU is also TSO approved with full rotor containment which provides protection from rotor non-containment.

To ensure that this circuit is working, each time the APU is stopped using the "STOP" switch, an overspeed reference frequency is generated and applied to the overspeed circuits to verify they generate an overspeed shutdown command, which results in both the withdrawal of power from the APU's internal fuel solenoid, causing it to close, and withdrawal of power to the fuel flow torque motor, causing it to restrict fuel flow to the APU. This provides redundant means to protectively shut down the APU. If the overspeed detection circuit fails, the ECU detects this, illuminates the "APU FAIL" light, and removes power from the fuel torque motor and fuel shutoff valve, causing them to close and shut down the APU.

Explanation of how design features or alternative standards provide an equivalent level of safety intended by the regulation

The following applies to the Cessna Model 680 standard equipment APU installation:

The intent of §§ 25.1305 and 25.1549 to permit crew monitoring and corrective action is inherently met by design with reliability at least as high as would be the case with analog cockpit indications of oil pressure, oil temperature, EGT, and RPM, and the associated colored range markings. In any event where the crew could observe an exceedance, or be provided with a low oil pressure warning, the APU would be shut down, and the crew alerted to the event. Since the APU is classified as non-essential equipment, no hazard is introduced by an automatic protective shutdown.

The following regards the Cessna Model 680 Sovereign's optional Honeywell RE100[CS] APU installation:

Prestart Test: When the APU master switch is turned on and power is applied to the ECU, the prestart test is automatically initiated. In this mode, the ECU and interface components are dynamically tested to verify operational readiness. The routine takes up to ten seconds. If a malfunction is found in the oil pressure, oil temperature, or EGT circuits, a start will be inhibited.

Periodic Tests: ECU periodic tests are performed automatically during a normal run sequence, commencing at the completion of the prestart BIT routine. These BIT tests are used to detect and isolate faults of the control system LRUs and APU automatic shutdown conditions. Open circuit or failure conditions in the oil temperature, EGT or speed sensing systems will be detected and result in a protective shutdown.

ECU monitoring of oil temperature, oil pressure, EGT and RPM, and automatic shutdown and informing the crew via an "APU FAIL" light in the event of an exceedance provides an equivalent function and level of safety to the crew monitoring of dial gages for these parameters marked in accordance with § 25.1549, and having to take the same protective shutdown action in the event of an exceedance.

FAA approval and documentation of the ELOS

The FAA has approved the aforementioned Equivalent Level of Safety Finding in Issue Paper P-1. This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the public. The Transport Directorate has assigned a unique ELOS Memorandum number (see front page) to facililitate archiving and retrieval of this ELOS. This ELOS Memorandum Number should be listed in the Type Certificate Data Sheet under the Certification Basis section. [E.g. Equivalent Safety Findings have been made for the following regulation: §§ 25.1305(a)(4), (a)(5), (a)(6), (c)(1) and (c)(3) – Powerplant Instruments and §§ 25.1549(a) through (c) – Powerplant and auxiliary power unit instruments (documented in TAD ELOS Memo TC2548WI-T-P-1)]

/s/

Signature: Neil D. Schalekamp
Manager, Propulsion/Mechanical Systems Branch, ANM-112

Date: April 28, 2004

ELOS Originated by Wichita ACO:	Program Manager, Tina Miller	Routing Symbol ACE-117W